COMP 308
ARTIFICIAL INTELLIGENCE
PART 2 – INTELLIGENT AGENTS

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Jan – April 2020

We Shall Discuss

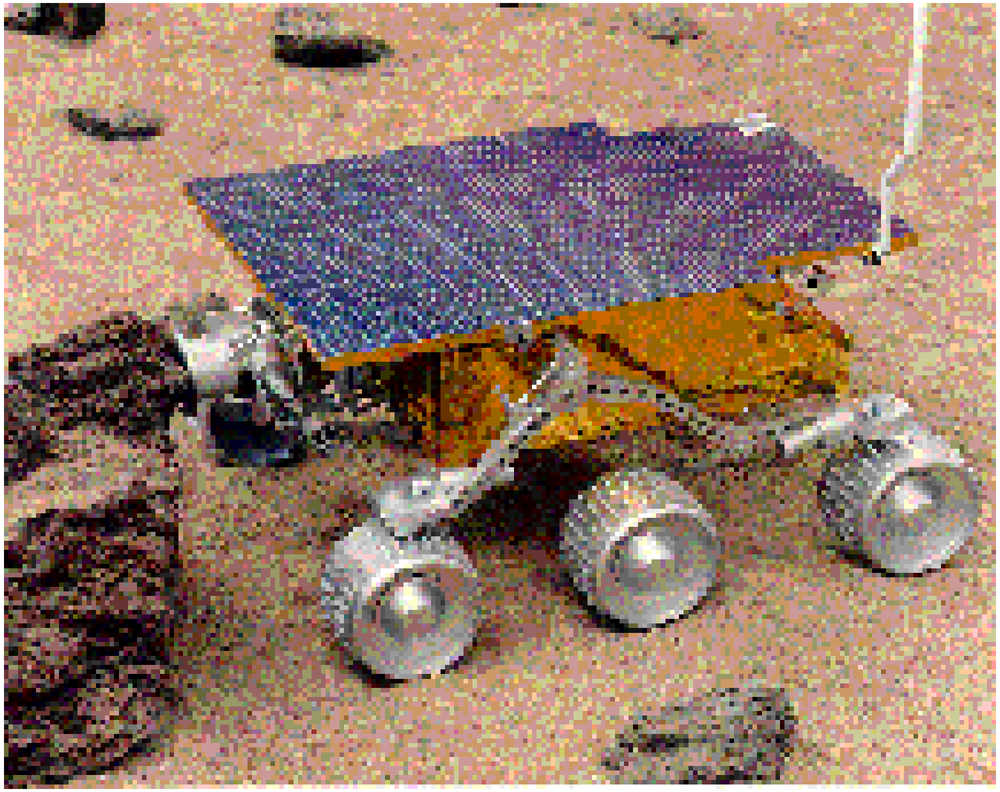
- What an agent is
- What an agents does
- How it is related to its environment
- How it is evaluated
- And how we might go about building one

Recap

- The mission of AI experts is to design / create
  - Computer programs that have some intelligence / can do some intelligent tasks / or can do tasks that require some intelligence
  - Computer programs capable of acting autonomously (independently) exhibiting control over their internal state

Mars Rover

- It is an autonomous device:
  - Exploring Mars, sending pictures to earth, camera, obstacle sensor, wheels, steering, turning,..

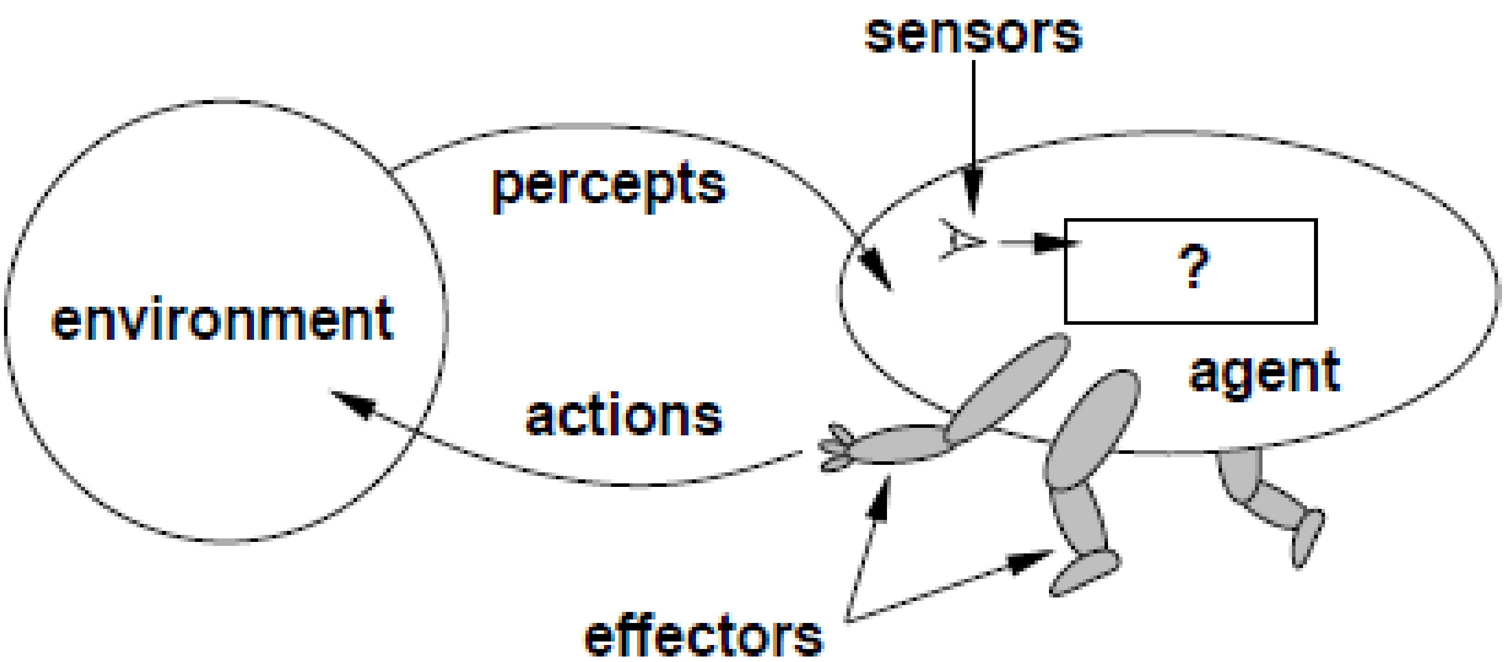


What is an (Intelligent) Agent?

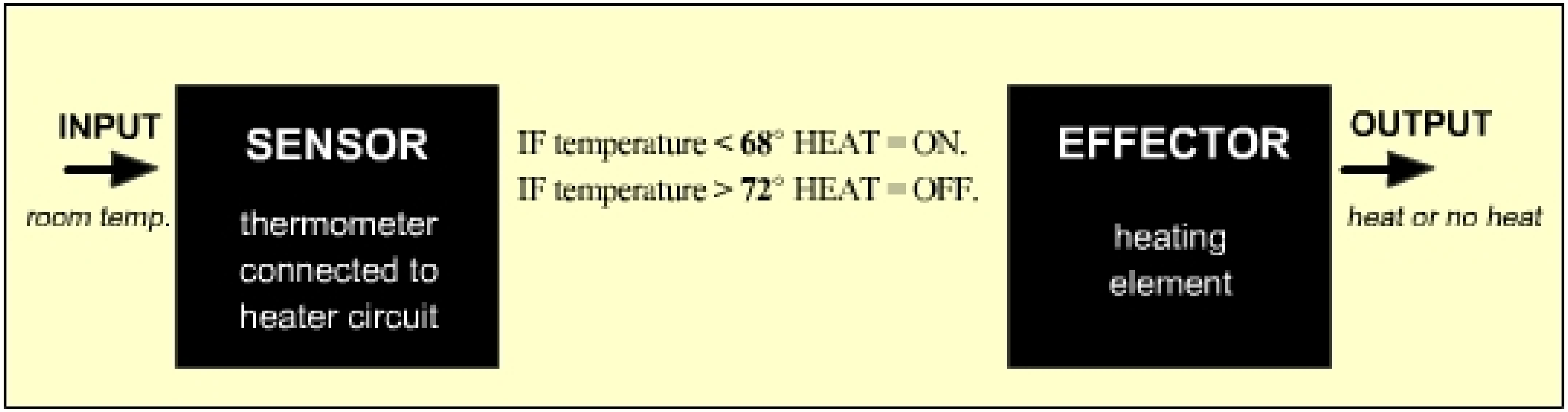
- Agent: An over-used, over-loaded, and misused term
- An **agent** is anything that can be *viewed as* **perceiving** its **environment** through **sensors** and **acting** upon that environment through its **effectors** to maximize progress towards its **goals**
- A **human agent** has eyes, ears, and other organs for sensors, and hands, legs, mouth, and other body parts for effectors
- A **robotic agent** substitutes cameras and infrared range finders for the sensors and various motors for the effectors
- **PAGE** (Percepts, Actions, Goals, Environment)
- An agent is task-specific & specialized, i.e.. It has well-defined <u>goals</u> and <u>environment</u>

Intelligent Agents

- Agents interact with environments through sensors and effectors



Intelligent Agents

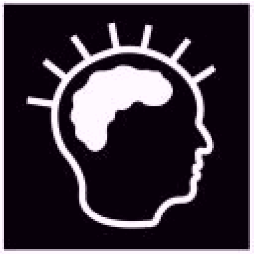


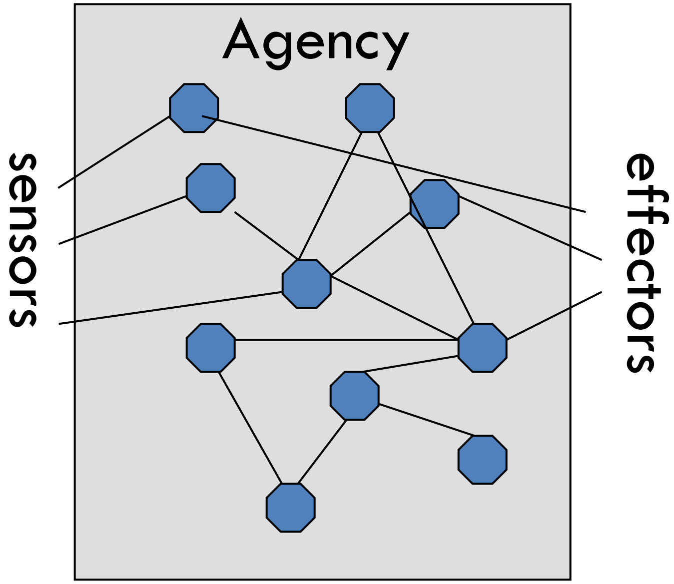
Thermostat Agent

- The is a simple agent that responds to a very specific feature of the environment with only three possible actions: turn heat on or turn heat off or take no action
- Such an agent does not really qualify as intelligent or autonomous, because its behaviour is too limited and lacks flexibility and adaptability to qualify as autonomous by definition
- Notice that even with a simple thermostat the environment determines the action of the agent and the agent's action, in turn, modifies the environment, in a relationship of mutual determination. When the temperature falls to 68 F the heat is turned on, but this brings the ambient temperature of the room to 80 F, which triggers an action to turn the heater off
- The environment is generally the domain or world of the agent

Intelligent Agents and Artificial Intelligence

- Human mind as network of thousands or millions of agents all working in parallel. To produce real artificial intelligence, this school holds, we should build computer systems that also contain many agents and systems for arbitrating among the agents' competing results





- Distributed decision-making and control

- Challenges:
  - Action selection: What next action to choose
  - Conflict resolution

Agent Research Areas

- We can split agent research into two main strands:
  - Distributed Artificial Intelligence (DAI) – Multi-Agent Systems (MAS) (1980 – 1990)
  - Much broader notion of "agent" (1990's – present)
    - interface, reactive, mobile, information

Examples of Intelligent Agents – Towards Autonomous Vehicles

A Windscreen Wiper Agent

- How do we design a agent that can wipe the windscreens when needed?
  - Goals?
  - Percepts ?
  - Sensors?
  - Effectors / Actuators ?
  - Actions ?
  - Environment ?

A Windscreen Wiper Agent

- Goals: To keep windscreens clean and maintain good visibility
- Percepts: Raining, Dirty, Clear
- Sensors: Camera (moisture sensor)
- Effectors: Wipers (left, right, back)
- Actions: Off, Slow, Medium, Fast
- Environment: Nairobi city, pot-holed roads, highways, weather … Nyahururu town?

Interacting Agents

Collision Avoidance Agent (CAA)

- Goals: Avoid running into obstacles
- Percepts ?
- Sensors?
- Effectors ?
- Actions ?
- Environment: River Road, Nairobi

Lane Keeping Agent (LKA)

- Goals: Stay in current lane
- Percepts ?
- Sensors?
- Effectors ?
- Actions ?
- Environment: Highway

Interacting Agents

Collision Avoidance Agent (CAA)

- Goals: Avoid running into obstacles
- Percepts: Obstacle distance, velocity, trajectory
- Sensors: Vision, proximity sensing
- Effectors: Steering Wheel, Accelerator, Brakes, Horn, Headlights
- Actions: Steer, speed up, brake, blow horn, signal (headlights)
- Environment: River Road, Nairobi

Lane Keeping Agent (LKA)

- Goals: Stay in current lane
- Percepts: Lane center, lane boundaries
- Sensors: Vision
- Effectors: Steering Wheel, Accelerator, Brakes
- Actions: Steer, speed up, brake
- Environment: Highway

Examples of Intelligent Agents

Agent	Goal	Percepts	Sensors	Effectors	Actions	Environment
Bin-Picking Robot	Parts in correct bins	Images	Vision	robotic arm	Grasp objects; Sort into bins	Parts in correct bins
Medical Diagnosis	Healthy patient	Patient symptoms, tests	Vision, Keyboard entry of symptoms,		Tests and treatments	Patient & hospital
Webcrawler Softbot	Collect information on a subject	Web pages			Follow links, pattern matching	Internet
Financial forecasting Software	Pick stocks to buy & sell	Financial data			Gather data on companies	Stock market, company reports

Agent Type	Performance Measure	Environment	Actuators	Sensors
Medical diagnosis system	Healthy patient, reduced costs	Patient, hospital, staff	Display of questions, tests, diagnoses, treatments, referrals	Keyboard entry of symptoms, findings, patient's answers
Satellite image analysis system	Correct image categorization	Downlink from orbiting satellite	Display of scene categorization	Color pixel arrays
Part-picking robot	Percentage of parts in correct bins	Conveyor belt with parts; bins	Jointed arm and hand	Camera, joint angle sensors
Refinery controller	Purity, yield, safety	Refinery, operators	Valves, pumps, heaters, displays	Temperature, pressure, chemical sensors
Interactive English tutor	Student's score on test	Set of students, testing agency	Display of exercises, suggestions, corrections	Keyboard entry

Examples of Intelligent Agents

Agent Type	Performance Measure	Environment	Actuators	Sensors
Taxi driver	Safe, fast, legal, comfortable trip, maximize profits	Roads, other traffic, pedestrians, customers	Steering, accelerator, brake, signal, horn, display	Cameras, sonar, speedometer, GPS, odometer, accelerometer, engine sensors, keyboard

Examples of Intelligent Agents

Agent	Goal	Percepts	Sensors	Effectors	Actions	Environment
Smartphone Personal Assistant						
AI bot in a gaming platform						
Online Chat bot						

The Right Thing = The Rational Action

- An **agent** gets percepts one at a time, and maps this percept sequence to actions, it should **act rationally** upon its environment in order to meet its design objectives
- A **rational agent** always performs **right action**
- **Rationality** is the status of being reasonable, sensible, and having good sense of judgment
- **Rational Action:** The action that maximizes the expected value of the performance measure <u>given the percept sequence to date</u>
  - Rational = Best ?
  - Rational = Optimal ?
  - Rational = Omniscience ?
  - Rational = Successful ?

The Right Thing = The Rational Action

- **Rational Action:** The action that maximizes the expected value of the performance measure <u>given the percept sequence to date</u>

  - Rational = Best — Yes, to the best of its knowledge
  - Rational = Optimal — Yes, to the best of its abilities (incl. its constraints)
  - Rational ≠ Omniscience
  - Rational ≠ Successful

- That leaves us with the problem of deciding ***how*** and ***when*** to evaluate the agent's performance

Behavior and Performance of IAs

- **How to Evaluate an Agent's Behavior/Performance?**
  - To measure **Rationality of an IA** consider the following factors:
    - The **performance measures,** which determine the degree of success
    - Agent’s **Percept Sequence** (history of all that an agent has perceived till date) till now
    - The agent’s **prior knowledge about the environment**
    - The **actions** that the agent can carry out

Behavior and Performance of IAs

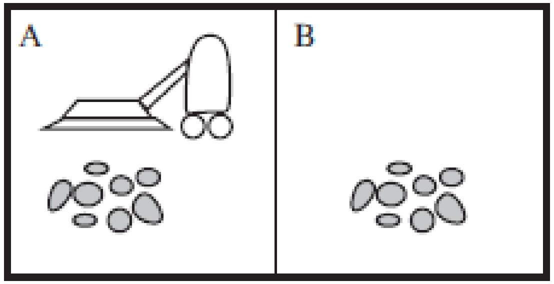
- **Agent Function = Perception** (sequence) to **Action Mapping**

$$f : \mathcal{P}^* \rightarrow \mathcal{A}$$

  - **Ideal mapping:** specifies which actions an agent ought to take at any point in time
  - **Description:** Look-Up-Table,..
- **Performance measure:** a *subjective* measure to characterize how successful an agent is (e.g., speed, power usage, accuracy, money, etc.)
- (degree of) **Autonomy:** to what extent is the agent able to make decisions and actions on its own?

Behavior and Performance of IAs

Example: Vacuum-cleaner Agent whose world with just two locations



- Percepts: Location and contents, e.g. [A, Dirty]
- Actions: Left, Right, Suck, NoOp
- Agent's Function → look-up table
  - For many agents this is a very large table

Percept sequence	Action
[*A*, *Clean*]	*Right*
[*A*, *Dirty*]	*Suck*
[*B*, *Clean*]	*Left*
[*B*, *Dirty*]	*Suck*
[*A*, *Clean*], [*A*, *Clean*]	*Right*
[*A*, *Clean*], [*A*, *Dirty*]	*Suck*
⋮	⋮

How is an Agent different from other software?

- Agents are **autonomous,** that is they act on behalf of the user
- Agents contain some level of **intelligence**, from fixed rules to learning engines that allow them to adapt to changes in the environment
- Agents don't only act **reactively**, but sometimes also **proactively**
- Agents have **social ability**, that is they communicate with the user, the system, and other agents as required
- Agents may also **cooperate** with other agents to carry out more complex tasks than they themselves can handle
- Agents may **migrate** from one system to another to access remote resources or even to meet other agents

Environment Types

- **Characteristics**
  - Accessible (observable) vs. inaccessible
    - An environment is accessible if the sensors detect all aspects that are relevant to the choice of action
  - Deterministic vs. non-deterministic
    - If the next state of the environment is completely determined by the current state and the actions selected by the agents, then we say the environment is deterministic
  - Episodic vs. non-episodic
    - In an episodic environment, the agent's experience is divided into "episodes." Each episode consists of the agent perceiving and then acting

Environment Types

- **Characteristics**
  - Static vs. dynamic
    - If the environment can change while an agent is deliberating, then we say the environment is dynamic for that agent; otherwise it is static
  - Discrete vs. continuous
    - If there are a limited number of distinct, clearly defined percepts and actions we say that the environment is discrete
  - Hostile vs. friendly
    - This depends on the agent perception

Environment Types

Environment	Accessible	Deterministic	Episodic	Static	Discrete
Operating System					
Virtual Reality					
Office Environment					
Mars					

Environment Types

Environment	Accessible	Deterministic	Episodic	Static	Discrete
Operating System	Yes	Yes	No	No	Yes
Virtual Reality	Yes	Yes	Yes/No	No	Yes/No
Office Environment	No	No	No	No	No
Mars	No	Semi	No	Semi	No

- The environment types largely determine the agent design

Environment Types

Task Environment	Observable	Agents	Deterministic	Episodic	Static	Discrete
Crossword puzzle	Fully	Single	Deterministic	Sequential	Static	Discrete
Chess with a clock	Fully	Multi	Deterministic	Sequential	Semi	Discrete
Poker	Partially	Multi	Stochastic	Sequential	Static	Discrete
Backgammon	Fully	Multi	Stochastic	Sequential	Static	Discrete
Taxi driving	Partially	Multi	Stochastic	Sequential	Dynamic	Continuous
Medical diagnosis	Partially	Single	Stochastic	Sequential	Dynamic	Continuous
Image analysis	Fully	Single	Deterministic	Episodic	Semi	Continuous
Part-picking robot	Partially	Single	Stochastic	Episodic	Dynamic	Continuous
Refinery controller	Partially	Single	Stochastic	Sequential	Dynamic	Continuous
Interactive English tutor	Partially	Multi	Stochastic	Sequential	Dynamic	Discrete

Structure of Intelligent Agents

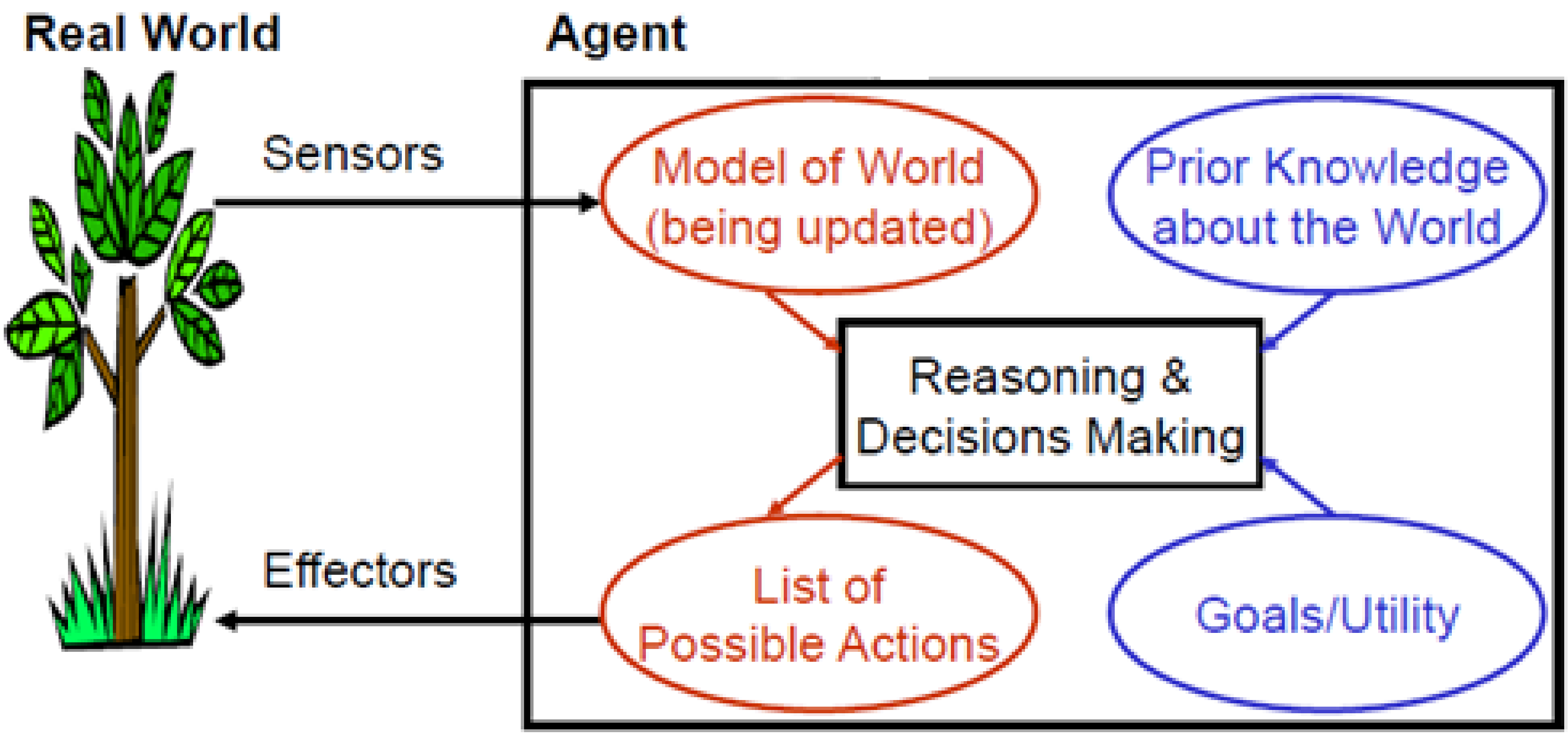
- **Agent** = architecture + program

- **Agent program:** the implementation of $f : \mathcal{P}^* \rightarrow \mathcal{A}$, the agent's perception-action mapping

function: Skeleton-Agent(*Percept*) **returns** *Action*
memory ← UpdateMemory(memory, *Percept*)
Action ← ChooseBestAction(memory)
memory ← UpdateMemory(memory, *Action*)
return *Action*

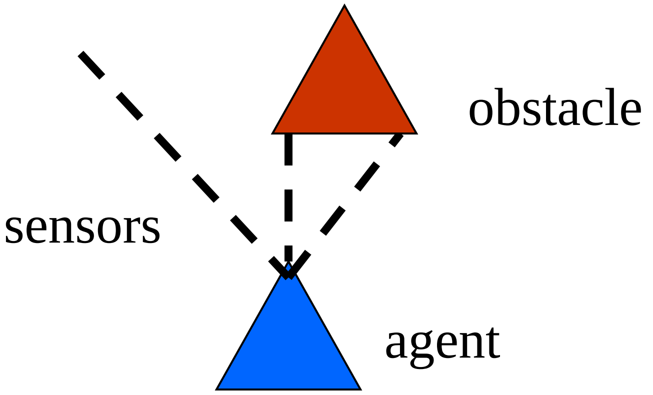
- **Architecture:** a device that can execute the agent program (e.g., general-purpose computer, specialized device, specialized, hardware/software, beobot, etc.)

Structure of Intelligent Agents



Using a look-up-table to encode $f : \mathcal{P}^* \rightarrow \mathcal{A}$

- **Example:** Collision Avoidance
  - Sensors: 3 proximity sensors
  - Effectors: Steering wheel, Brakes
- How to generate?
- How large?
- How to select action?



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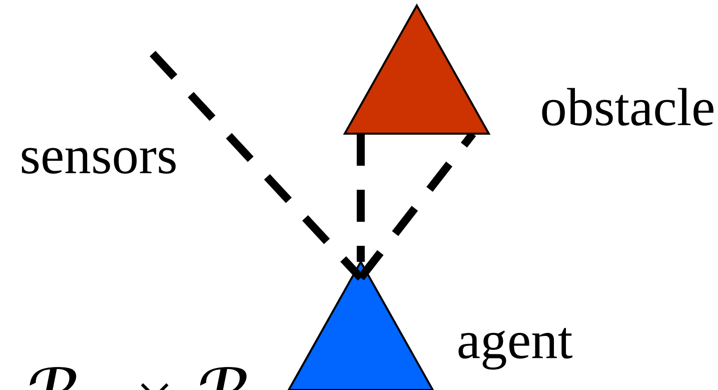


- How to generate: for each $p \in \mathcal{P}_l \times \mathcal{P}_m \times \mathcal{P}_r$ generate an appropriate action, $a \in \mathcal{S} \times \mathcal{B}$

- How large: size of table = #possible percepts times # possible actions = $|\mathcal{P}_l|\ |\mathcal{P}_m|\ |\mathcal{P}_r|\ |\mathcal{S}|\ |\mathcal{B}|$
  E.g., P = {close, medium, far}^{3}
  A = {left, straight, right} × {on, off}
  then size of table = 27*3*2 = 162

- How to select action? **Search**

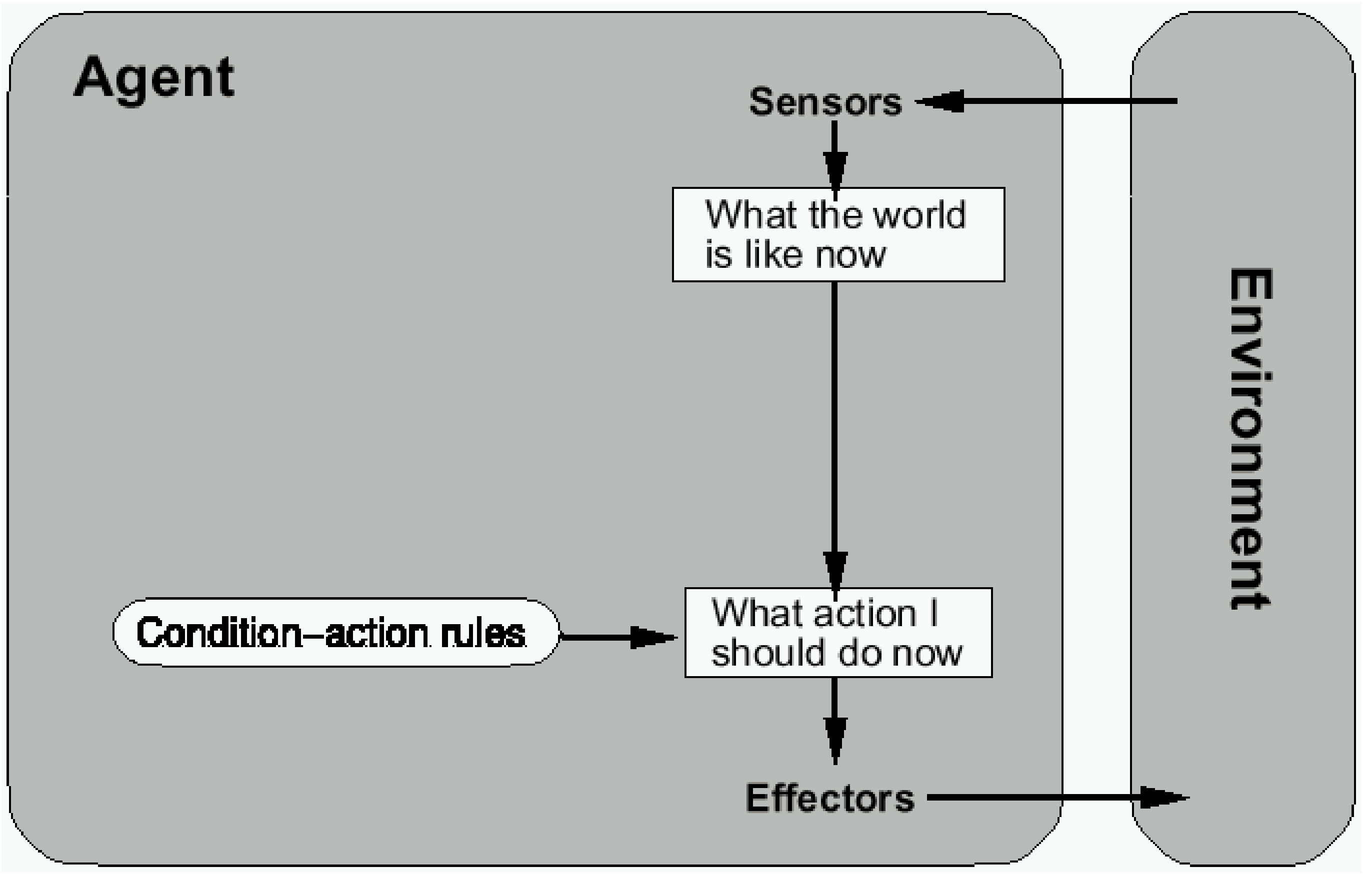
Exercise

- Consider any of the agent examples discussed earlier. The aim of this exercise is to determine the ideal mapping for the agent. Determine:
  - How to generate a look up table for the agent?
  - How large the agents look up table would be?

Agent Types

- Reflex agents
- Reflex agents with internal states
- Goal-based agents
- Utility-based agents
- Learning agents

Reflex agents

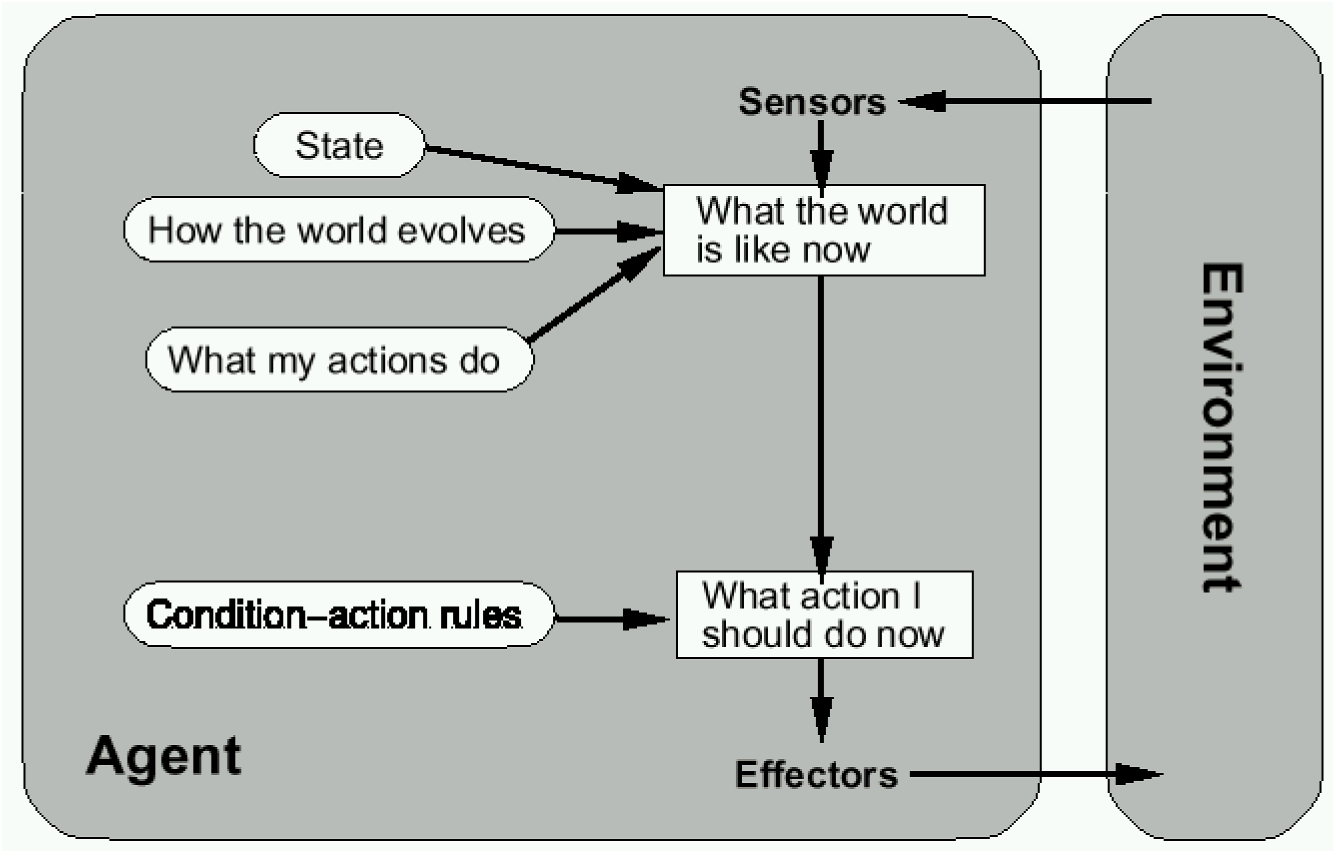


Reflex agents

- Reflex/Reactive agents do not have internal symbolic models i.e. **do not have memory of past** world states or percepts
- So, actions depend solely on **current percept.** They act by stimulus-response to the current state of the environment
- Action becomes a "reflex"
- Each reactive agent is simple and interacts with others in a basic way
- Complex patterns of behavior emerge from their interaction

- **Benefits:** robustness, fast response time
- **Challenges:** scalability, how intelligent?
  and how do you debug them?

Reflex agents with state

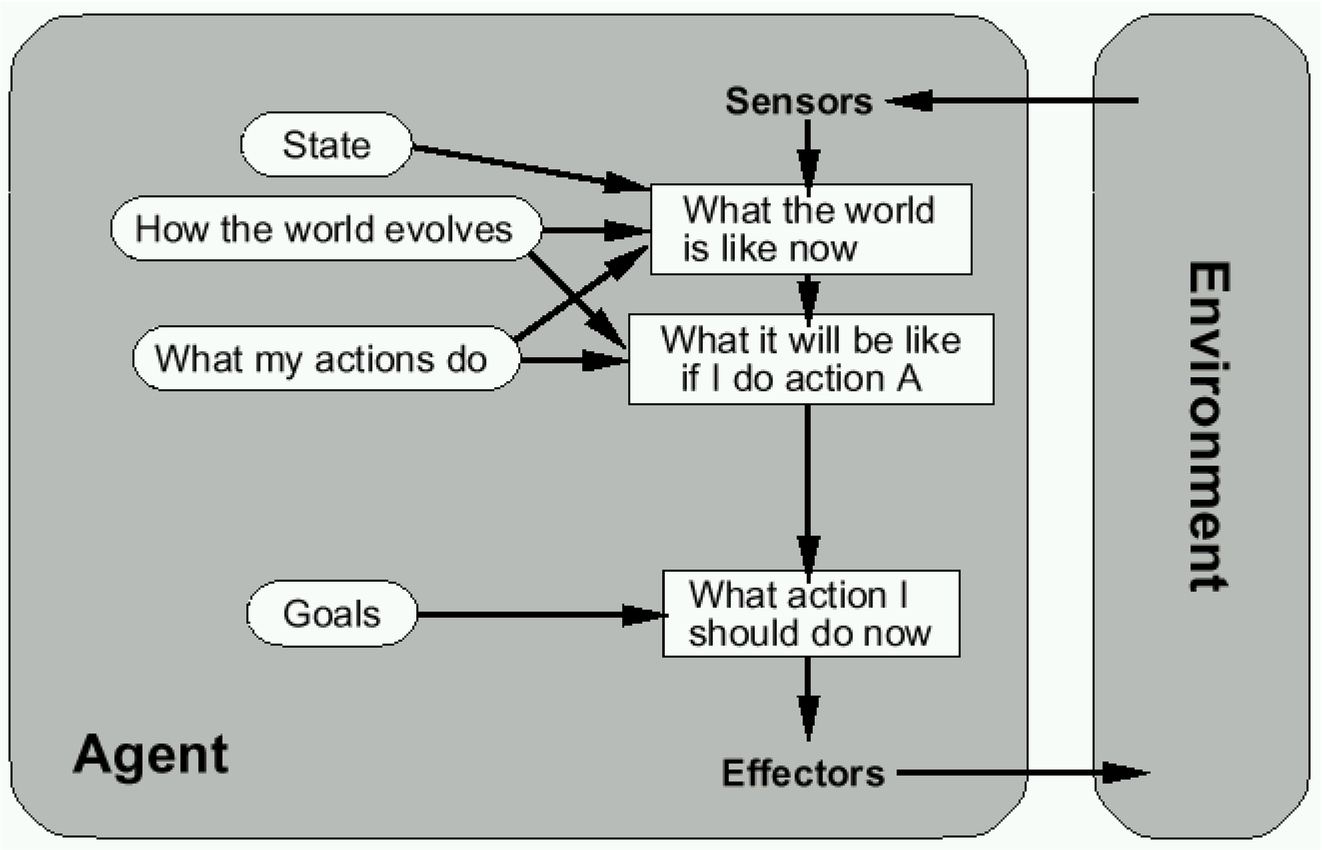


Reflex agents with state

- Also known as Model-based reflex agents
- Key difference with regards to simple reflex agents:
  - Agents have **internal state**, which is used to keep track of past states of the world
  - Agents have the ability **to represent change in the World**

- **Main idea**: build complex, intelligent robots by decomposing behaviors into a hierarchy of skills, each defining a percept-action cycle for one very specific task
- **Examples**: collision avoidance, wandering, exploring, recognizing doorways, etc.

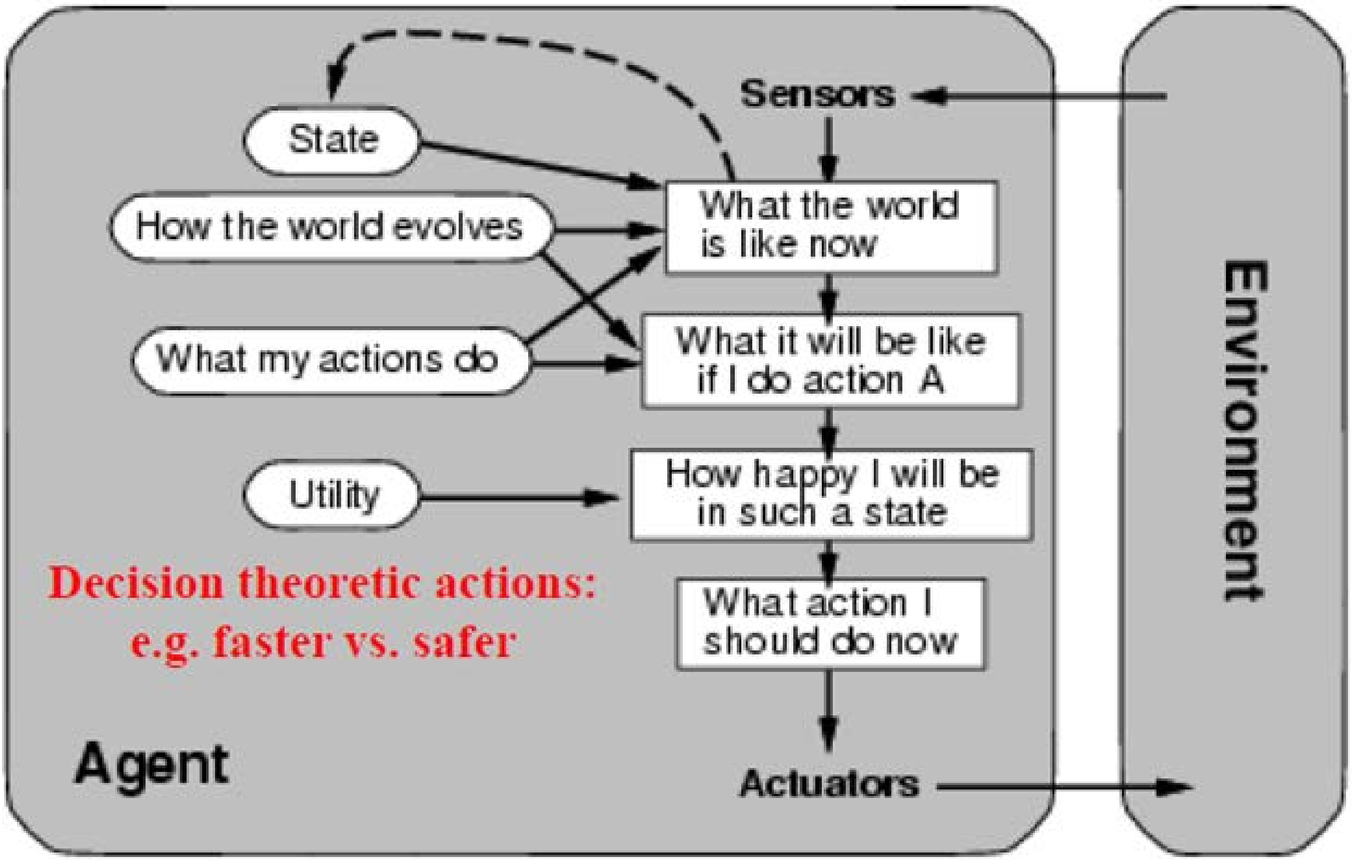
Goal-based agents



Goal-based agents

- Key difference with regards to Model-Based Agents:
  - In addition to state information, have **goal information** that **describes desirable situations to be achieved**
- Agents of this kind take future events into consideration.
  - **What *sequence* of actions can I take to achieve certain goals?**
- Choose actions so as to (eventually) achieve a (given or computed) goal
- ***problem solving and search!***

Utility-based agents



Utility-based agents

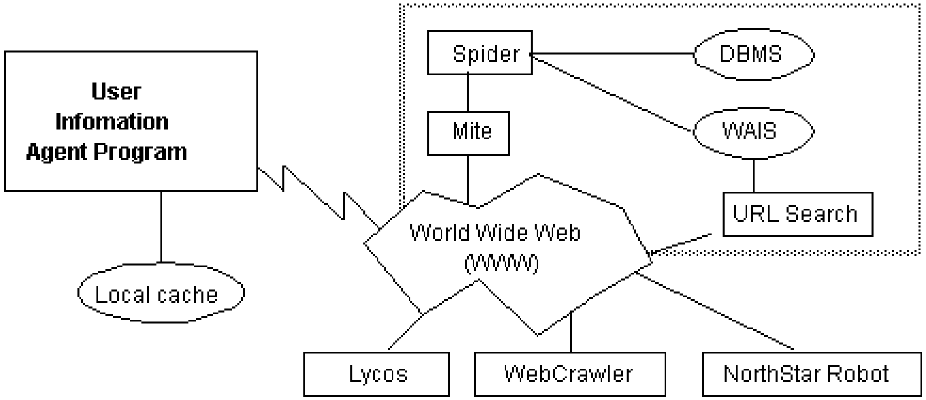
- When there are **multiple possible alternatives**, how to decide which one is best?
- Goals are qualitative: A goal specifies a crude distinction between a happy and unhappy state, but often a more general performance measure that describes "degree of happiness"
  - **Utility function U: State → R** indicating a measure of success or happiness when at a given state
- Important for making tradeoffs: Allows decisions comparing choice between conflicting goals, and choice between likelihood of success and importance of goal (if achievement is uncertain)
- ***Use decision theoretic models: e.g. faster vs. safer***

Mobile agents

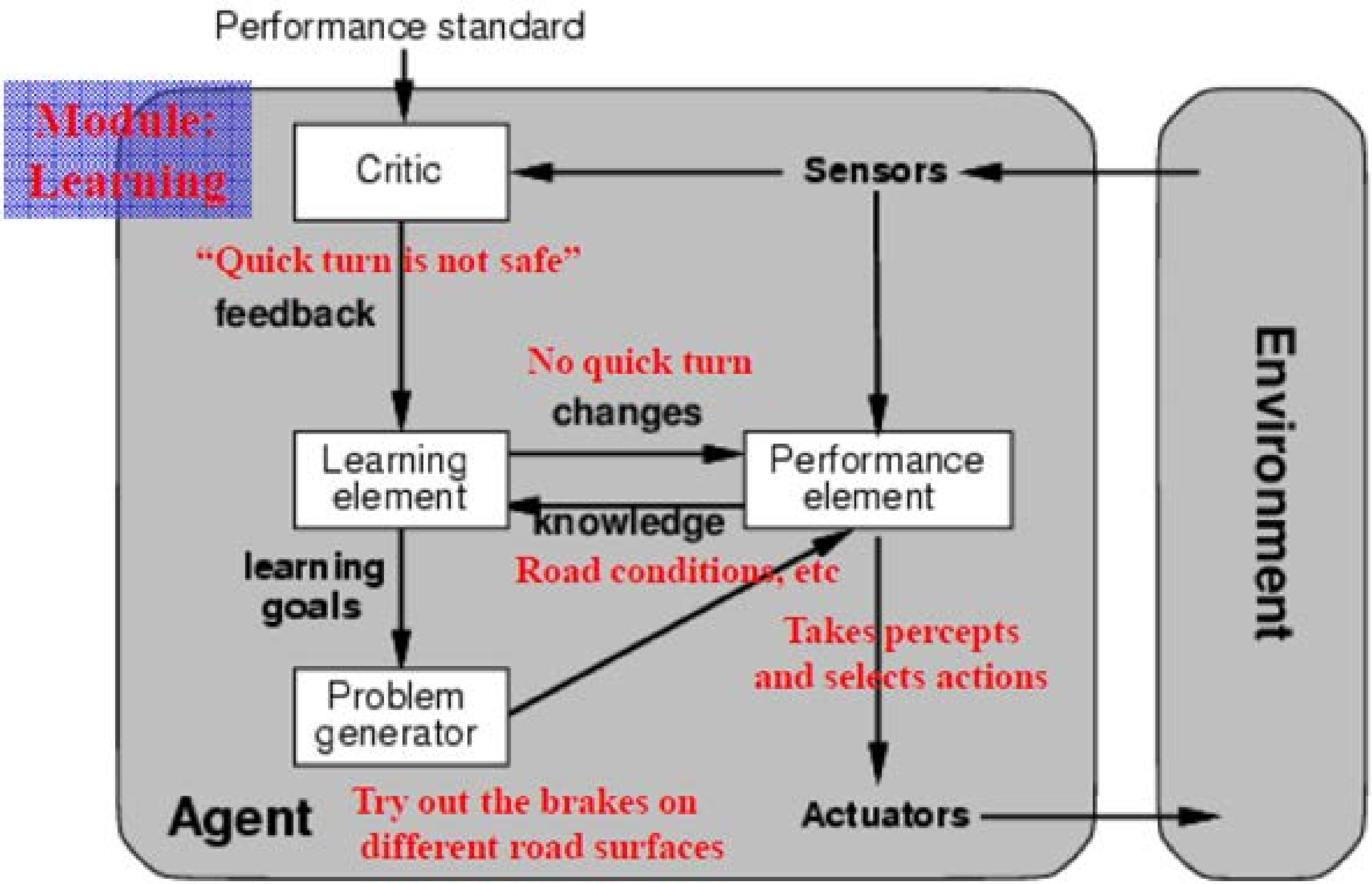
- Programs that can migrate from one machine to another
- Execute in a platform-independent execution environment
- Require agent execution environment (places)
- Mobility not necessary or sufficient condition for agenthood
- Practical but non-functional advantages:
  - Reduced communication cost (e.g., from PDA)
  - Asynchronous computing (when you are not connected)
- Two types:
  - One-hop mobile agents (migrate to one other place)
  - Multi-hop mobile agents (roam the network from place to place)
- Applications:
  - Distributed information retrieval.
  - Telecommunication network routing.

Information agents

- Manage the explosive growth of information.
- Manipulate or collate information from many distributed sources.
- Information agents can be mobile or static.
- Examples:
  - BargainFinder comparison shops among Internet stores for CDs
  - FIDO the Shopping Doggie (out of service)
  - Internet Softbot infers which internet facilities (finger, ftp, gopher) to use and when from high-level search requests.
- Challenge: ontologies for annotating Web pages (e.g., SHOE).



Learning agents



Learning agents

- Learning Agents **Adapt** and **Improve** over time
- More complicated when agent needs to learn **utility information:**
  - Reinforcement learning (based on action payoff)

Summary

- **Intelligent Agents:**
  - Anything that can be *viewed as* **perceiving** its **environment** through **sensors** and **acting** upon that environment through its **effectors** to maximize progress towards its **goals.**
  - PAGE (Percepts, Actions, Goals, Environment)
  - Described as a Perception (sequence) to Action Mapping:

$$f : \mathcal{P}^* \rightarrow \mathcal{A}$$

  - Using look-up-table, closed form, etc.

- **Agent Types:** Reflex, state-based, goal-based, utility-based, learning

- **Rational Action:** The action that maximizes the expected value of the performance measure <u>given the percept sequence to date</u>

Summary

- Simple reflex agents – are based on condition-action rules, implemented with an appropriate production system. They are stateless devices which do not have memory of past world states
- Agents with memory - Model-based reflex agents – have internal state, which is used to keep track of past states of the world.
- Agents with goals – Goal-based agents – are agents that, in addition to state information, have goal information that describes desirable situations. Agents of this kind take future events into consideration
- Utility-based agents – base their decisions on classic axiomatic utility theory in order to act rationally
- Learning agents – they have the ability to improve performance through learning

Exercise

- Differentiate between:
  - Agent
  - Rational Agent
  - Autonomous Agent